LinCom CORPORATION

COMPATIBLE ELECTRONICS

114 OLINDA DRIVE, BREA, CA 92821 · (714) 579-0344

May 17, 1995

Engineering Procedure used for Lincom Antenna Calibration

Two broadband antennas were set up with a 10 meter separation on the ANSI C63.4 open field test site of Compatible Electronics, Brea Division. The transmitting antenna was mounted on a tripod at a height of 1.5 meters. The receiving antenna was mounted on an antenna mast at a height of 1.8 meters, which is approximately the height of the Lincom Antenna when it is mounted on the truck. In the frequency range of 137 MHz to 500 MHz, reference readings were taken throughout this range by transmitting a field of 120 dBuV with one broadband antenna, and was received using another broadband antenna. The antenna mast with the receiving antenna was then moved away, and the truck, with the Lincom antenna was then placed where the mast was, maintaining the separation of 10 meters between antennas. Readings were then taken at all of the previously noted reference frequencies with the Lincom antenna, in order to find the antenna factor (see data sheets for calculations). A full set of readings were taken with the truck at 0, 90, 180 and 270 degrees.

Scott McCutchan

Scott McCutchan
Test Engineer

LinCom CORPORATION

ANTENNA CALIBRATION

COMPANY NAME: LinCom LAB: A DATE: 5-17-95

MODEL: S/N: ENGINEER: Scott McCutchan

TRANSMIT ANTENNA HEIGHT: 1.5 METERS FIXED - RECEIVED ANTENNA HEIGHT - 1.8 METERS FIXED SIGNAL GENERATOR OUTPUT: 120 dBuV
SPECTRUM ANALYZER SETTINGS: RESOLUTION AND VIDEO BANDWIDTH: 100 kHz
QUASI PEAK DETECTOR: "BYPASS"

Frequency MHz	Referenc e Level	Level (A)	(B)	X = (A) - (B)	Factor (Y)	Antenna Factor = (X) + (Y)
137	117.7	84.7	66.7	18.0	11.8	29.8
150	117.6	84.4	76.7	7.7	12.5	20.2
175	117.3	82.1	59.8	22.3	14.4	36.7
200	117.3	74.7	59.3	15.4	14.9	30.3
225	117.0	65.1	59.7	5.4	16.2	21.6
250	117.1	73.5	56.3	17.2	16.9	34.1
275	117.0	72.6	64.7	7.9	18.2	26.1
300	116.8	87.3	72.3	15.0	12.4	27.4
350	116.5	88.9	73.0	15.9	17.5	33.4
400	116.0	89.4	77.2	12.2	12.8	25.0
450	115.6	87.8	79.1	5.7	14.3	23.0
500	115.5	87.6	67.4	20.2	15.3	35.5
388.1			78.0			
402.5			77.0			
405.237			76.9			
415			72.1			
455.5			78.3			
495.5			72.7			

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QUASI PEAK DETECTOR: "BYPASS"

Frequency MHz	Reference Level	Level (A)	(B)	X = (A) - (B)	Factor (Y)	Antenna Factor = (X) + (Y)
137	117.7	84.7	65.2	19.5	11.8	31.3
150	117.6	84.4	71.3	13.1	12.5	25.6
175	117.3	82.1	62.5	19.6	14.4	34.0
200	117.3	74.7	64.6	10.1	14.9	25.0
225	117.0	65.1	63.8	1.3	16.2	17.5
250	117.1	73.5	60.3	13.2	16.9	30.1
275	117.0	72.6	61.0	11.6	18.2	29.8
300	116.8	87.3	70.4	16.9	12.4	29.3
350	116.5	88.9	71.4	17.5	17.5	35.0
400	116.0	89.4	74.5	14.9	12.8	27.7
450	115.6	87.8	76.0	11.8	14.3	26.1
500	115.5	87.6	68.1	19.5	15.3	34.8
388.1			70.4			
402.5			74.2			
405.237			74.4			
415			76.7			
455.5			78.2			
495.5			78.4			

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ANTENNA CALIBRATION

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Frequency MHz	Referenc e Level	Level (A)	(B)	X = (A) - (B)	Factor (Y)	Antenna Factor = (X) + (Y)
137	117.7	84.7	63.5	21.2	11.8	33.0
150	117.6	84.4	62.6	21.8	12.5	34.3
175	117.3	82.1	64.4	17.7	14.4	32.1
200	117.3	74.7	51.6	23.1	14.9	38.0
225	117.0	65.1	58.7	6.4	16.2	22.6
250	117.1	73.5	60.3	13.2	16.9	30.1
275	117.0	72.6	69.1	3.5	18.2	21.7
300	116.8	87.3	68.0	19.3	12.4	31.7
350	116.5	88.9	75.4	13.5	17.5	31.0
400	116.0	89.4	70.3	19.1	12.8	31.9
450	115.6	87.8	68.0	19.8	14.3	34.1
500	115.5	87.6	59.6	28.0	15.3	43.8
388.1			75.7			
402.5			67.1			
405.237			68.8			
415			62.4			
455.5			65.3			
495.5			65.9			

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ANTENNA CALIBRATION

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TRANSMIT ANTENNA HEIGHT: 1.5 METERS FIXED - RECEIVED ANTENNA HEIGHT - 1.8 METERS FIXED SIGNAL GENERATOR OUTPUT: 120 dBuV
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Frequency MHz	Reference Level	Level (A)	(B)	X = (A) - (B)	Factor (Y)	Antenna Factor = (X) + (Y)
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300	116.8	87.3	69.9	17.4	12.4	29.8
350	116.5	88.9	66.6	22.3	17.5	39.8
400	116.0	89.4	79.9	7.5	12.8	22.3
450	115.6	87.8	77.0	10.8	14.3	25.1
500	115.5	87.6	80.6	7.0	15.3	22.3
388.1			77.4			
402.5			80.4			
405.237			80.8			
415			81.8			
455.5			76.6			
495.5			81.1			

Antenna Factor Relation to Antenna Gain[1]

The term "Antenna Factor" (AF) was originated to treat the antenna as a transducer between an ambient electric field (E volts/meter) and a voltage (V volts) at the end of a terminated transmission line(into a spectrum analyzer). Electric field strength(E) can be measured, using an antenna with a known antenna factor(AF) by using the dBμv setting on the spectrum analyzer and adding the antenna factor to arrive at the field strength(E) in dB μv/meter.

$$20\log(E)(dBv/m) = 20\log(V)(dBv) + AF(dB) \qquad (1)$$

The following will show the relation of the above units to communication engineer units of RIP(power received by a hypothetical isotropic antenna), antenna gain relative to an isotropic antenna, and power in dbm at the spectrum analyzer.

The power, P_{rec} received or "captured" by an antenna may be written in the form

$$P_{sa} = P_{rec} = P_d A_e \qquad (2)$$

where P_d is the power density in watts/m^2 and A_e is the effective area of the antenna in square meters. The received power is assumed to be delivered to the spectrum analyzer and any losses are accounted for in the effective area. Equation (2) may be written in terms of the voltage at the spectrum analyzer and the power density may be written in terms of the electric field at the antenna. Substituting for those, we have

$$\frac{V^2}{2R_L} = \frac{E^2}{2R_{sp}} A_e \qquad (3)$$

where R_L is the spectrum analyzer impedance(50 Ω) and R_{sp} is the impedance of free space(120π Ω). The Gain of an antenna is the ratio of the effective area of the antenna to that of an isotropic antenna. The effective area of an isotropic antenna is given by

$$A_{iso} = \frac{\lambda^2}{4\pi} = \frac{1}{4\pi}\frac{c^2}{f^2}, \qquad (4)$$

where λ is the wavelength in meters, c is the speed of light ($3\text{x}10^8$ meters/sec), and f is the frequency in Hz.

[1] The authors acknowledge Dr. Nick Wagner's contributions to the antenna factor analysis.

Now we can write (3) as

$$\frac{V^2}{2R_L} = \frac{E^2}{2R_{sp}} G \frac{1}{4\pi} \cdot \frac{c^2}{f^2} \tag{5}$$

Converting to dB, we have (6)

$$20\log(V) - 10\log(2R_L) = 20\log(E) + 10\log\left(\frac{c^2}{8\pi R_{sp}}\right) + G_{db} - 20\log(f)$$

or

$$20\log(E) - 20\log(V) = 10\log\left(\frac{c^2 R_L}{4\pi R_{sp}}\right) - G_{db} + 20\log(f).$$

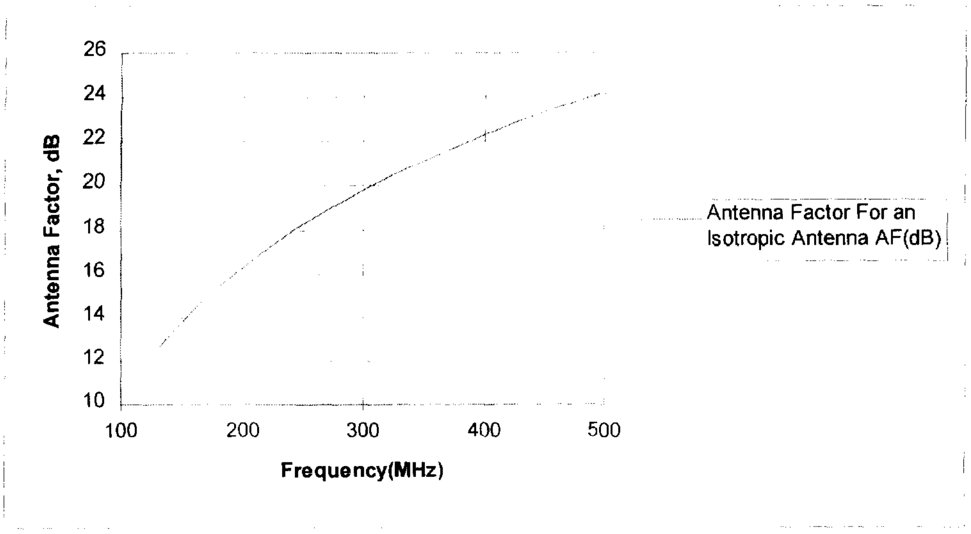
Recognizing the left hand side as the antenna factor, we may the write

$$AF = 10\log\left(\frac{c^2 R_L}{4\pi R_{sp}}\right) - G_{db} + 20\log(f)\,. \tag{7}$$

Finally, inserting the constants and taking f in MHz, we have the relation between the antenna factor and gain of an antenna.

$$AF == -29.78 - G_{db} + 20\log(f_m) \tag{8}$$

The antenna factor is graphed below for 0 dB gain.



The second part of this exposition is to predict the signal level ambient at the antenna given the power reading on the spectrum analyzer. This has already been addressed in equation (1), however the units used are not intuitive to everyone. In this section, the relation between spectrum analyzer power (P_{sa}) and RIP(P_{iso}) will be derived.

The power received by an isotropic antenna is

$$P_{iso} = P_d A_{iso} = P_{sa} / G, \qquad (9)$$

where G(in dB) is obtained from (8). The RIP then is given in dB by

$$\hat{P}_{iso} = \hat{P}_{sa} + 29.78 + AF - 20\log(f_m) \qquad (10)$$

where the "hat" indicates the quantity in dB.